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The Beauty of Understanding: Scientific Understanding as Aesthetic Experience

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Our standard images of science and scientists fail to portray the way in which scientists themselves experience science—as an aesthetic quest. They ignore the way in which scientists are driven by a passion for beauty and a childlike thirst to understand. In this post, we draw upon an original large-scale international study of scientists and pragmatist theories of aesthetics and inquiry to explain why and how scientists experience science aesthetically. We further argue that the *beauty of understanding*, which is at the heart of science, can enhance not only the practice of science but the lives of us all.

Max Weber (1958) famously characterized modernity as entailing a fragmentation of the social order into distinct, autonomous, and conflicting value-spheres. The scientific sphere, in particular, was seen as opposed not simply to religion but also to aesthetics. Today, science is seen as a rational, methodical, analytical, and objective endeavor (e.g., Reiss and Sprenger 2014), while the aesthetic sphere is characterized by emotion, subjectivity, irrationality and even a resistance to rationalization (Gane 2002, 111). Among the public, scientists are often seen as socially dysfunctional, middle-aged, myopic white males in lab coats, busy with tedious experimentation (Kahle 1993; Long and Steinke 1996).

By contrast, writings of scientists in recent decades have emphasized the aesthetic dimensions of science, and the role of beauty, awe, and wonder in scientific inquiry (e.g., Chandrashekar 1987; Dirac 1963; Dawkins 1998; Feynman 2005; Wilczek 2016). The picture we get from these accounts is of science as a profoundly emotional, passionate, and aesthetic endeavor, in which symmetry and elegance are often used as heuristics for truth (Dirac 1980; Gell-Mann 2007). Such accounts, however, come predominantly from Nobel Prize winners and celebrity scientists, leaving open the question of whether scientists more generally experience science aesthetically.

To empirically assess the prevalence, meaning, and value of aesthetic experiences among scientists, we conducted the first international study to explore the role of aesthetics in scientific work, which includes survey data from nearly 3500 scientists and in-depth interviews with 215 scientists from physics and biology departments in four countries: India, Italy, the UK, and the US. We branded the study as “[Work and Well-being in Science](#)” so as not to attract only those keen to talk about aesthetics. The full details of our survey methodology can be found in our report [here](#).

Our findings lead us to conclude that the process of science is more akin to an aesthetic quest, and scientists like impassioned artists or creative children. Our standard images of science and scientists fail to portray the way in which *scientists themselves* experience science. They ignore the way in which scientists are driven by a passion for beauty and a childlike thirst to understand. We draw upon pragmatist theories of aesthetics and inquiry to explain why and how scientists experience science aesthetically, and to suggest why recognizing this can enhance not only the practice of science but the lives of us all.

## The Varieties of Beauty in Science

Scientists often encounter beauty in various aspects of their work. Most scientists in the countries we studied (75%) find beauty encounter beauty in the phenomena they study (e.g., cells, particles, etc.). These phenomena often evoke feelings of childlike delight or awe in scientists. 81% of scientists report feeling a sense of childlike delight or joy during their work, and 83% of scientists report feeling their research opened up new mysteries for them to explore at least a few times a year.

Scientists also claim to find beauty in how they do their work: 52% of scientists encounter beauty in the process of scientific research. They find beauty in the technology, experiments, and theories with which they engage in research.

Scientists also find beauty in the more relational aspects of their work, as in teaching, for instance, where 54% of scientists encounter beauty.

Yet there is another way in which scientists experience science aesthetically: in the *beauty of understanding*, which is a deep aesthetic pleasure that comes from gaining new insight into how reality works—grasping the hidden order, inner logic, or causal mechanisms underlying natural phenomena. This type of aesthetic experience seems to order and orient the aforementioned aesthetic experiences.

One US biologist and Nobel laureate we interviewed ascribed beauty to what he called moments of “aesthetic recognition.” By this he meant that there is beauty when you “leap to the truth” or “leap to a sense of generalization or something that is beyond the particular – [that] in some way represents the real thing that's going on.”

Scientists across career stages, disciplines, and countries emphasized moments of understanding as deeply aesthetic. A graduate student in physics in the UK describes moments of understanding as on par with “looking into the face of God for non-religious people.”

In fact, 77% of scientists in the countries we surveyed ascribe beauty to “hidden order or patterns” or the “inner logic of systems.” And 87% report that they felt a sense of clarity as they saw how things fit together, at least a few times a year during the course of their scientific work.

Scientists experience the beauty of understanding not only as clarifying, but also as deeply fulfilling, satisfying. As one Indian biologist told us, “[T]he most fulfilling part is when we are trying to question something, when we hypothesize something, and we have a sort of understanding of it in our head...that is the best part. [...], once we get the answer that moment is very, very - we cherish that moment.”

Through understanding, scientists told us, they feel “reconciled” and in “harmony” with nature. “I think one of our driving purposes being human in an inhuman material world,” a

UK physicist said to us, “is to understand the inhuman material world better and be reconciled to it. And I think that’s what science does. That’s one of the most beautiful and deep and poetic activities one can pursue as a human being.”

How can we explain this? Why is understanding, for scientists, an aesthetic experience?

### **Scientific Understanding as Aesthetic Experience**

To answer this question, we turn to the work of pragmatist philosopher John Dewey. Dewey’s philosophical work is vast, but its “central, guiding thought,” according to Thomas Alexander (1987), is precisely “the aesthetic dimension of experience.”

In *Art as Experience*, Dewey thematizes experience as the qualitative effects of the “interaction” between “organism and environment” (1934, 22). Experience is a “rhythm” (1934, 23, 58), Dewey writes, “of struggle and consummation” (1934, 23). In its phase of struggle or disintegration, experience is what Dewey calls “anesthetic” (1934, 41). What Dewey calls “*an* experience” or aesthetic experience is achieved when the anesthetic transforms into experience that is satisfying, integrated, consummate (1934, 37).

Dewey in fact compares science and art (as conventionally understood) to demonstrate that even seemingly disparate practices like these share the aesthetic potential he thinks characterizes experience generally. While acknowledging differences between them, Dewey thinks science and art differ not in kind, but rather in “tempo and emphasis” (1934, 14). Art and science alike, in his view, are oriented to reconstructing experience, or transforming anesthetic into aesthetic experience. Indeed, the potential for aesthetic experience, Dewey thinks, is key to why artists and scientists do what they do. He writes, “No thinker can ply his occupation save as he is lured and rewarded by total integrative experiences that are intrinsically worthwhile” (1934, 38)—that is, aesthetic experiences. And achieving aesthetic experience, Dewey thinks, arouses a sense of beauty, prompting remarks like “How beautiful,” as Dewey writes in his essay “Qualitative Thought,” to “mark[s] the realized appreciation” of the aesthetic quality of the experience (1930, 250).

While Dewey does not spell out specifically what aesthetic experience in science is, our research with scientists points us to the *beauty of understanding* as the aesthetic experience at the heart of the scientific endeavor (cf. Tschaepé 2013). Moments of understanding bring scientists a sense of clarity, satisfaction, harmony—exactly what, to Dewey, defines aesthetic experience. And it is the beauty of understanding that “lures” and “rewards” scientists in their work.

The beauty of understanding is what orders and orients all that scientists find beautiful about science—from being drawn in by the beauty of nature to going about their research to teaching, and thereby facilitating and witnessing the beauty of understanding on the part of others.

Dewey's insights, then, give us a framework for seeing science as an aesthetic quest, and scientists as driven to achieve the beauty of understanding.

### **The 'How' of Scientific Inquiry**

In discussing science in aesthetic terms, Dewey's purpose was not to develop a full-fledged account of the aesthetic nature of science. So to explain *how* scientific inquiry can lead to the beauty of understanding, we turn for further insights to the theory of scientific inquiry developed by Charles S. Peirce, the founder of pragmatism, to which Dewey's aesthetics is deeply indebted (see, e.g., Innis 2017; 2019).

Peirce developed a theory of inquiry that centered belief and doubt: "The irritation of doubt causes a struggle to attain a state of belief. I shall term this struggle *inquiry*" (1877, 114). Science advances, in Peirce's view, when extant frameworks (beliefs) are disrupted (thrown into doubt) by things not easily accommodated by the expectations a framework set up.

The "emotion of surprise" indexes the conflict between expectations and observations (1901, 88; on Peirce's concept of indexical signs, see Peirce 1895, 13; cf. Ritz 2022, 522, n. 10), prompting what Peirce calls "abduction," a mode of inference distinct from deduction and induction by which one alights upon a hypothesis that, if true, would explain the surprising phenomenon (e.g., 1903, 205). The "struggle" of inquiry proceeds, then, until the best of reasoning, observation, and experiment indicate it is reasonable to accept what began as an abductive hypothesis provisionally as an "established truth" (1898, 56)—on the understanding that it is fallible, and at best may be only partial.

In Peirce's view, engaging in scientific inquiry is the best way to learn what is true about reality (1877, 120-123; 1878, 138-139)—even if knowledge is never certain. But it depends on what Peirce calls the "Will to Learn" or "a hearty and active desire to learn what is true" (1898, 47; cf. Haack 2014). It also depends on participating in a community of inquiry (1868, 29) where what Peirce calls the "social impulse" counters tendencies to slip into non-scientific methods of "fixing belief" (1877, 116).

### **Questing for the Beauty of Understanding**

Integrating Peirce's and Dewey's insights with our own from analyzing examples scientists shared about times they experienced the beauty of understanding, we offer the following account of how scientific inquiry can lead to the beauty of understanding.

It depends, first and foremost, on having what we call (in a Peircean spirit) *the habit of wonder*. Wonder (also see Keil 2022), or the desire to learn, must be a habit so that it is available for arousal by the *emotion of surprise* in unexpected encounters. Surprise can take a variety of forms. It may come in the form of delight at a pleasant sight you did not expect. It may come in the form of awe at something that transcends your understanding (see Keltner 2023). Surprise may come in its prototypical form when one finds oneself surprised by novel observations in experimental work. Or, surprise may come in the form of disappointment or

confusion upon failed predictions. For those with the habit of wonder, surprise lands like a seed on fertile ground, and the struggle or quest of scientific inquiry begins.

We can think of this quest as unfolding in a continuous series of circuits, an image Dewey favored (see, e.g., Dewey 1896). The task of the scientist is to close a circuit of inquiry by connecting fact and theory, theory and fact. Any particular circuit offers two distinct paths to closure. One is the path from surprise, which we already alluded to. As Peirce observed, feeling surprised means your theoretical framework is lacking. So the scientist who is surprised must move in a theoretical direction to close the circuit of inquiry, seeking theory that fits the surprising fact. This was the case of the US biologist quoted below, who emphasized surprise when describing for us the way her own research trajectory spun out from a time her postdoc found a gene where no one expected it to be, prompting new theorizing about the evolution of the gene.

I was sort of surprised and amazed. I was proud of [my postdoc] for persisting in something that he thought really was a thing, even though I told him I didn't think that could be right. But he wasn't deterred by his advisor who had more experience and more knowledge than him saying that she didn't think that could be the case. [...] I was extremely excited because there's nothing I love better than learning something new that I would never have guessed based on what I already knew, that for me is one of the things I love best in life. [...] And that means, now there's a whole new world of possibilities to explore we didn't even know were there.

Another route to the beauty of understanding is the *path toward discovery*, which we do not find discussed in the work of Dewey or Peirce but is something the scientists we interviewed often described. Sometimes the scientist has a theory but has not observed the fact it predicts. The task then is to move in an empirical direction to achieve closure, seeing whether the fact the theory predicts is out there to be found.

A common example our interviewees mentioned illustrating the role of discovery is the discovery of the Higgs Boson, which they described by evoking ideas of closure, satisfaction, and beauty. As one Italian physicist put it, “When they did find Higgs Boson at the CERN,” it was like “closing a quest.”

Now, following the suggestions of surprises or pursuing data for discoveries is no easy journey. The scientist struggles to connect theory and fact through experimental failure and even more mundane difficulties like broken code, supply shortages, and more. Nor is it an isolated one. It requires company, colleagues, mentors, people to push back and help you forward—as Peirce recognized in emphasizing the importance of the community of inquiry.

But when the scientist’s journey leads to the meeting of fact and theory, it is deeply satisfying, as expressed in the “aha” in the UK physicist’s quote below.

Once I understood it, I suddenly thought, ‘aha, that’s what it is,’ right. [...] And so, once you realize that this is the way of thinking about it, suddenly everything -- it’s like the fog lifts. You go, ‘aha, this is what it is.’ That’s -- it gives you a sense of, it’s amazing, it’s very exciting, but you feel like you’ve understood something.

From the closure of a circuit of inquiry emerges understanding, which bears an aesthetic quality by virtue of the fact that it transforms a situation marked by disintegrated observations and ideas into an integrated, coherent system. This is the “consummation” Dewey sees as the height of aesthetic experience.

And, as with aesthetic experience generally, the sense of closure that comes with scientific understanding is not that of a “cessation,” but a “consummation” (1934, 37). It is not a “terminus,” but, as Alexander writes, “it is a closing together which holds within it the opening of the world” (1987, 204). Scientific understanding is generative: it opens new circuits of inquiry, bringing into view new horizons that beckon for understanding.

### **Why Recognizing Science as an Aesthetic Quest Matters**

What is the upshot of recognizing that science is an aesthetic quest for the beauty of understanding?

Scientists themselves stand to benefit from recognizing the major role beauty plays in their own experiences. Many scientists we talked to waxed poetic about the beauty they encounter in science—to us, but admitted they rarely talk about this with their colleagues. They had no idea whether other scientists shared their love for beauty, nor did they feel comfortable trying to find out. “Beauty” is just not part of scientists’ lexicon, they told us, for better or worse. We think that’s for the worse.

Recognizing the beauty of understanding makes it a resource for encouraging scientists to persist through the struggles of inquiry, or for appealing to imaginative, creative young minds who might consider careers in science. Perhaps more importantly, it raises the stakes of figuring out how science as an institution can better nurture wonder, collegiality, and openness to surprise and discovery (i.e., intellectual humility), and how it can cultivate opportunities for surprise—which many scientists we interviewed suggest are too often stifled or missed due to institutional pressures to “publish or perish” and bring in grant funding.

But it is not just scientists who stand to benefit from recognizing the beauty one can encounter in understanding. We all can, because the beauty of understanding is not restricted to scientists who work in labs. As Peirce and Dewey (see Dewey 1938, 3) recognized long ago, and as psychologists and philosophers from Alison Gopnik (1998) to Mark Johnson (2007) have emphasized in recent decades, the kind of inquiry scientists engage in is on a continuum with how all of us are capable of engaging experience in everyday life, from infancy into adulthood. The beauty of understanding is available to us all, every time we

learn something new or discover whether what we thought we knew is right or wrong. From scientists, we can model ways to cultivate it by keeping both eyes open to the surprises and discoveries in everyday life, by building solidarity in our polarized communities, and by elevating the wondering child in all of us.

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